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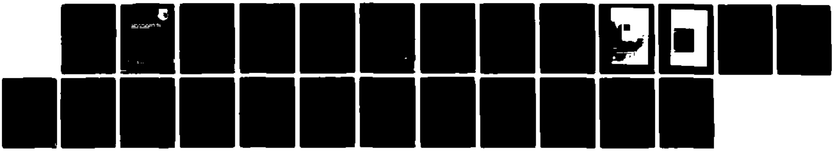

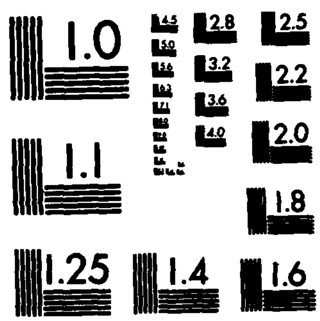

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THE EFFECT OF SIZE AND NUMBER (DENSITY) OF MINOR OPTICAL OCCLUSIONS ON TARGET DETECTION PERFORMANCE

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SEPTEMBER 1982

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AFAMRL-TR-83-48

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FOR THE COMMANDER

CHARLES BATES JR
Chief
Human Engineering Division
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A study was conducted to determine the effect of size and number (density per unit area) of minor optical defects contained in an aircraft transparency on aircrew visual performance. Eight subjects performed a target detection task while looking through 13 simulated "windscreen" test panels. These panels contained defects of size 0.032, 0.043 or 0.35 inches in diameter that varied in number from 11, 22, 33 or 44 per panel. The targets to be detected simulated an aircraft with a frontal plane of 40 feet located at a range of 24,500

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feet (0.5 minutes of arc) or 49,000 feet (1.0 minute of arc) being viewed under fairly clear atmospheric conditions (80% contrast) or poor atmospheric conditions (10% contrast). Subject performance was measured in terms of time to detection and percent correct detection. The results obtained indicated that target size and target contrast significantly affected performance, however the number and size of defects on the "windscreen" had no effect on performance. Based on this latter finding, it is concluded that current standards and specifications concerning the number and size of minor optical defects permitted on aircraft transparencies may be safely relaxed without adversely affecting aircrew visual performance. A recommendation is also made that an alternative method for determining the "goodness" or "badness" of a transparency be employed. Such a method would be based on a percentage of a given area of the transparency that may be obstructed by optical defects.

PREFACE

This report was prepared by the Crew Systems Effectiveness Branch of the Human Engineering Division, Air Force Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH. The work was performed under Task 718418, "Visual Effects of Windscreens on Pilot Performance," Work Unit 71841802, "Optical Properties of Windscreens." The authors wish to express their sincere thanks and appreciation to Ms. Mary Ann Howes and Becky Unger who contributed much time and effort to the successful completion of this study. Funding for this project was provided by the Air Force Wright Aeronautical Laboratories, Flight Dynamics Laboratory, Vehicle Equipment ADP Branch (AFWAL/FIEA).

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SECTION 1
INTRODUCTION

Historically, optical specifications for the manufacture and acceptance of aircraft transparencies demand extremely stringent quality control and inspection procedures. Most of these optical specifications, although purporting to be based on a foundation of visual performance, are in actuality a reflection of the state-of-the-art in material availability and handling procedures. A case in point is the specification dealing with minor defects contained in aircraft transparencies.

Several military standards and specifications state the number and size of minor defects which are allowable in various areas of aircraft transparencies. MIL-G-5485C (ref. 1) allows certain spot-like inclusions so long as they are less than 0.063 inches in diameter. MIL-G-25667B (ref. 2) specifies the allowable number of minor defects with respect to the area of daylight opening and the thickness of the part, allowing more defects in thicker samples (as if spots were less noticeable in thicker parts than in thin ones).

Transparency industry handbooks usually include some remarks about minor defects. A common maximum limit allows defects up to 0.093 inches in maximum dimension, however defects over 0.063 inches are not allowed within 2 inches of each other. "The total number of optical defects for the applicable panel size and thickness shall not exceed the sum of the totals permitted by MIL-P-5425, MIL-P-8184, MIL-P-25690, or MIL-P-83310 for the individual glass or plastic plies, plus a certain number of defects for each interlayer" (ref. 3).

In addition to these general standards, each aircraft has its own set of specifications which seems to be independent of both the standard and the specifications for other aircraft. The following paragraphs describe some of the acceptance standards that are specific for some of the current aircraft.

The acceptance test procedure for F-111 windscreens (ref. 4) allows opaque inclusions of less than 0.035 square inches in area but permits no more than 12 such defects in the entire panel should these defects be between 0.035 and 0.070 square inches in size. Transparent defects up to 0.35 square inches in area are permitted "provided they do not cause a vision impairment".

Current General Dynamics and USAF requirements for F-16 canopies (ref. 5) allow minor defects that cover an area that is equivalent to or less than a 0.035 inches diameter circle but limit larger defects to less than 20 per zone. Opaque particles can be no larger than 0.070 square inches in area, and there will be no more than 12 particles between 0.035 and 0.070 square inches per panel.

The specification for the F-5 (ref. 6) allows no minor defects in the "supercritical area" (equivalent to the design eye), but the critical area may have one spot per square foot as long as that spot is no larger than the area covered by a circle of 0.25 inch diameter. More than one spot of this size is permitted only if the defects are located in such positions that 2 or more cannot be encompassed in 1 square foot area circular template.

Although many of these specifications are commendable from the visual standpoint, they seem to have little, if any, uniformity and apparently do not relate to the visual aspects of flight. The imposition of optical requirements that have no effect on structural integrity, aerodynamics, or visual processes can only lead to a more expensive part with no performance gain on the part of the pilot.

The purpose of this effort is to determine the effect of opaque defects of various sizes and densities (number per unit area) on air-to-air target acquisition. Since target acquisition is an extremely critical task and since performance on this task is most likely to be disrupted by opaque occlusions in the canopy or windscreen, data gathered from these experiments will contribute to the formation of new visual/optical specifications for aircraft transparencies relative to minor defects.

SECTION 2
METHODOLOGY

DESIGN VARIABLES

The independent variables investigated in this experiment were target size (0.5 and 1.0 minutes of arc), target contrast (80%, 10%), defect size (0.35, 0.093 and 0.032 inch diameters), and total number of defects per test panel or unit area (11, 22, 33, or 44). Combinations of these four variables resulted in a total of 48 treatment conditions (2 x 2 x 3 x 4). Dependent variables employed were percent correct detections and detection time.

SUBJECTS

A total of 8 subjects (6 males and 2 females) obtained from a paid subject pool were used. All subjects were administered refractive visual examinations and all exhibited normal or corrected acuity of 20/20 or better. If necessary, these subjects could have passed a Flying Class II eye examination. All subjects were considered to be "experienced", each having served as subjects in other studies similar to this one. All subjects were tested under all 48 treatment conditions employed. Each subject served a total of 15 sessions over a period of 15 days.

TASK

The task employed simulated an air-to-air target detection task performed through a windscreen containing a number of opaque defects. The target to be detected differed in size and contrast and appeared at random locations within a 14° field of view. The scenario used simulated an aircraft pilot performing an in-cockpit visual task followed immediately by an out-the-cockpit visual search of a segment of the sky. The visual conditions of this task are considered to be similar to those experienced by a pilot who is monitoring his radar screen and then looking out of the aircraft to obtain a visual fix.

APPARATUS

The apparatus used consisted of the following major pieces of equipment — a background screen, simulated aircraft targets, an experimenter's station, a subject's station, a 35 mm carousel slide projector, and 13 simulated windscreen test panels.

BACKGROUND SCREEN

The background screen, approximately 5 x 7 feet in size, consisted of a foam rubber mat mounted on a wall and covered with a white sheet. It was used to provide a homogenous background against which the targets could be viewed. Uniform illumination of the screen was achieved by two vertically mounted 8-foot fluorescent lamps located four feet from the screen and set 5½ feet apart.

TARGETS

The targets used were made from four straight pins, two black and two gray. Two pinheads subtended a visual angle of 0.5 minutes of arc while the other two pinheads subtended an angle of 1.0 minutes of arc. These target sizes were designed to produce a retinal image corresponding to an aircraft with a head-on frontal area of 40 square feet at a range of either 24,500 or 49,000 feet. Under the conditions employed, the contrast of the targets were 80% and 10%.

EXPERIMENTER'S STATION

The experimenter's station was comprised of the necessary electrical components and accessories that allowed the experimenter to (1) control the on-off cycle of the fluorescent lights, (2) control the on-off cycle of the subject's reading lamp, (3) automatically record the subject's detection time, and (4) reset the entire sequence for the next trial.

SUBJECT'S STATION

The subject's station consisted of a black wooden fixture with a 17.5 inch square viewing aperture mounted on a table and located 15 feet from the background screen. The fixture was used to hold the simulated windscreen test panels. The height from the center of the viewing aperture to the floor was 48 inches. Also located at the subject's station were a reading lamp, a response button, and a word search puzzle book. The subject sat on a standard straight-back chair located 18 feet from the background screen and 3 feet from the viewing aperture.

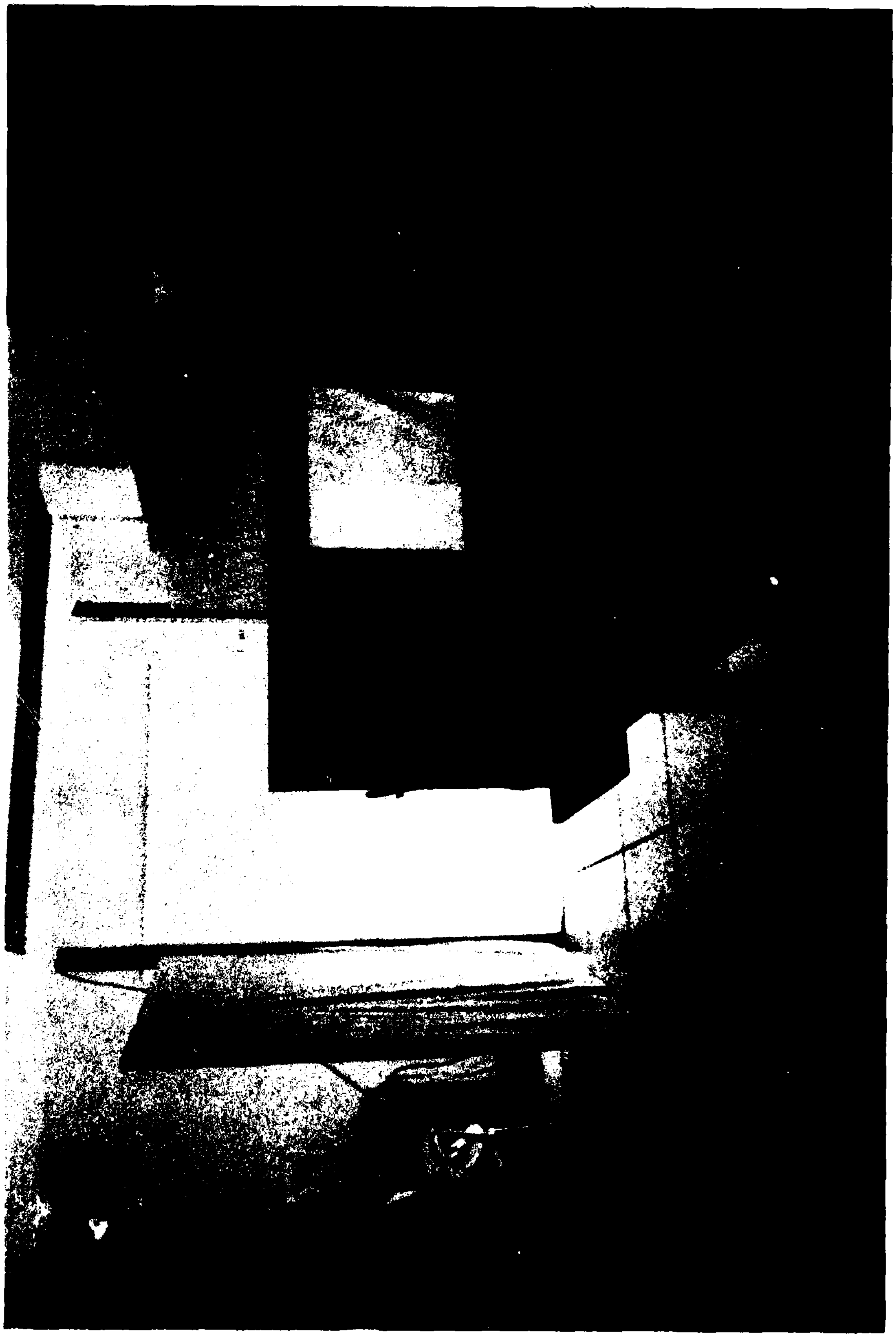

Figure 1. Experimental Setup Showing the Subject's Station (Forefront), Experimenter's Station (Left) and Background Screen

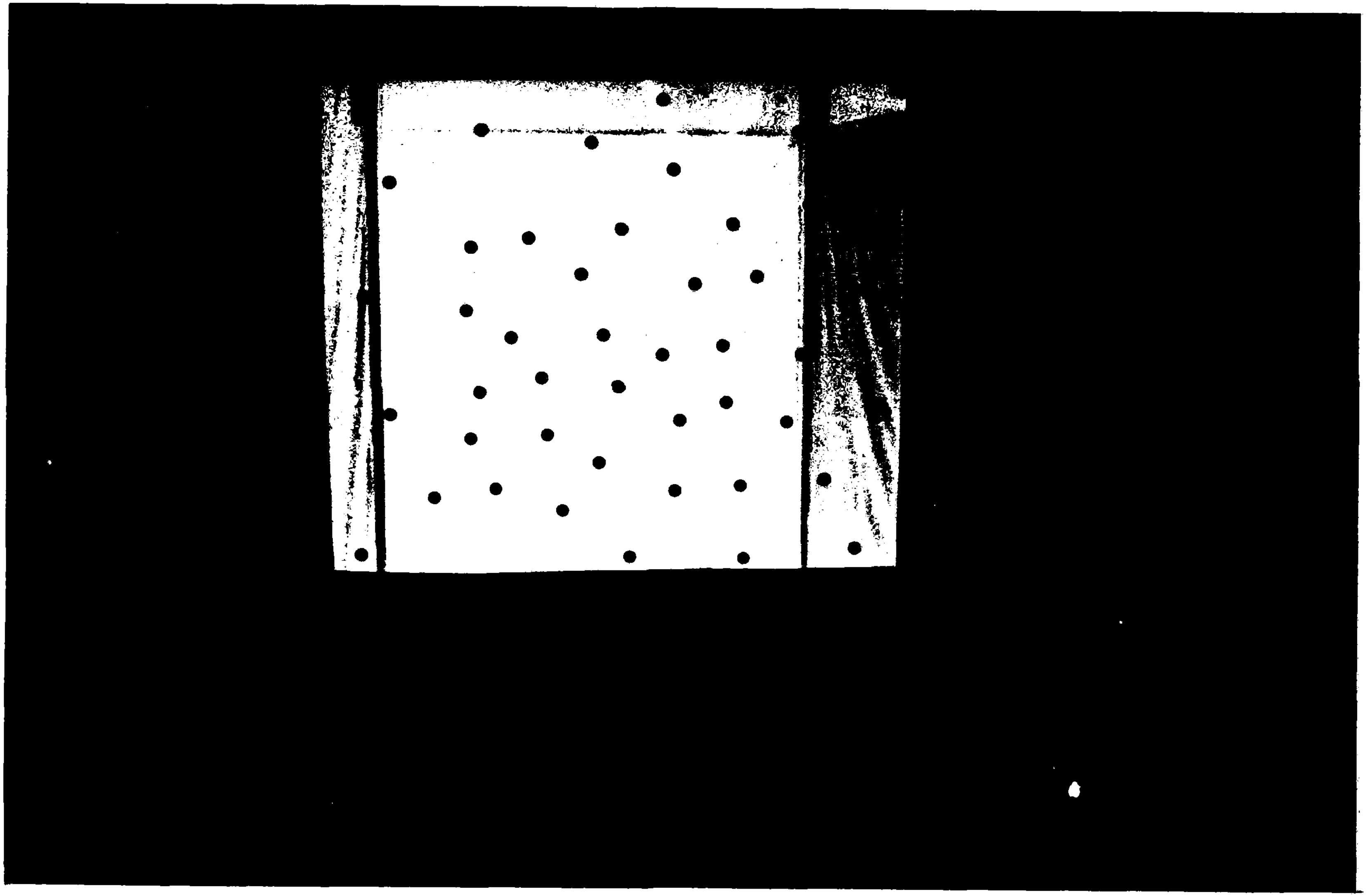

Figure 2. One of the test panels (0.35 inch size, 44 in number) used in the study.

SLIDE PROJECTOR

The 35 mm slide projector was located 28 feet from the background screen at a height of 8 feet. It was used to project a black grid containing white lines and lettering on the screen for a period of 2 seconds immediately after the subject activated his response button. The grid was used by the subject to indicate the location of the target on the screen after detection. Although both the grid and target were on the screen simultaneously, the target was never simultaneously visible to the subject due to both the target and the grid being black.

WINDSCREEN TEST PANELS

The thirteen simulated windscreen panels were made from plastic sheets 17.5 inch square and 1/8 inch thick. One panel was clear and contained no defects. The other 12 panels represented the various combinations of defect size (3) and number of defects per panel (4) used. The defects were simulated by using appropriate size circular, black chartpak die cut symbols and pasting them on the panels in the appropriate number. The location of the "defects" on the panels was random.

Figure 1 depicts the experimental set up used in this study showing the experimenter's station (left), the subject's station (center) and the background screen. Figure 2 shows one of the test panels (0.35 inch diameter defect size and a density of 44 defects) used.

PROCEDURE

During the conduct of this experiment, the following procedure was adhered to: each subject was required to serve for a total of 15 sessions over a period of 15 days. These 15 sessions were divided into two segments of 7 and 8 days each. During the first segment (the first 7 sessions) the subjects were tested with the high contrast targets while in the second segment (the last 8 sessions) they were tested with the low contrast targets. Both segments were separated by a period of one week. On the first day of each segment, when the subject arrived at the test site he was instructed about the purpose of the experiment, the task to be performed, and the manner in which he was to respond. Any and all questions were answered at this time. The subject was then seated at the subject's station where he was able to view the background screen located 18 feet away through the simulated windscreen test panel mounted 3 feet from him and perpendicular to his line of sight. He was then given 15 practice trials using a 2 minute of arc high contrast target. After a short rest period, he was given 6 pretest trials (3 with each target size) followed by 20 trials using the clear, zero-defect test panel (10 trials per target size) followed by 6 post test trials. In subsequent sessions, each subject was tested under two of the treatment conditions employed (i.e., with two different test panels). Under each treatment condition, he performed 6 pre test trials, 20 test trials, followed by six post test trials. Rest periods were provided between each treatment conditions. After the completion of the second test segment, the subjects were again tested with the zero-defect panel. This was done in order to determine if any learning (training) effects had occurred over the previous 7 sessions.

During a given trial, the following sequence of events occurred: the test room was darkened except for the reading lamp located at the subject's station. While the subject attended to his word search task, the experimenter manually inserted one of the targets into the background screen. After doing so, the experimenter pushed a start button which activated a timer and turned on the two vertically mounted fluorescent lights which illuminated the background screen. The turning on of the fluorescent lights turned off the subject's reading lamp and signalled him (her) to switch his attention from the word search task to the target detection task. As soon as the subject detected the target, he pushed his response button. This action stopped the timer, turned off the two fluorescent lights, and opened an optical shutter on the slide projector. This last action resulted in a black, 5 x 5 grid with white lines and lettering being projected on the background screen. Using the grid, the subject verbally indicated the location of the target on the screen to the experimenter. The grid remained on the screen for a period of 2 seconds. When it went off, the subject's reading lamp came back on. As soon as his reading lamp came back on, the subject went back to his word search task and the experimenter changed the location of the target on the screen. The entire sequence of events was then repeated until the appropriate number of trails had been completed.

SECTION 3
RESULTS

The results of this study are presented in Figures 3 to 8. These figures provide a detailed look at the data obtained in terms of the specific effects of size and number of defects on performance. The data used to generate these curves are presented in Table 1 and 2.

As noted in Table 1, the average time to correctly detect the 1.0 minute (24,500 foot range), 80% contrast target using the zero-defect test panel was 3.2 seconds while for the 10% contrast target the average time was 11.8 seconds. For the 0.5 minute (49,000 foot range) target, these average times increased to 17.2 and 20.0 seconds for the 80% and 10% contrast targets respectively.

Interposition of a panel containing defects 0.032 inches in diameter did not significantly affect performance (Figure 3). The average time to detect the 1.0 or the 0.5 minute high contrast (80%) target was 2.7 and 15.9 seconds respectively. When contrast was reduced to 10%, the average time to detection for these same targets increased to 12.8 and 19.4 seconds respectively. Although a defect of 0.032 inches is allowable under currently employed acceptance procedures, the number of defects per panel greatly exceeded present specifications.

Using a panel containing defects that exceeded the acceptance standard in terms of size (0.093 inches) and the specifications for number in a given area (1 to 2 per square foot), performance once again was not found to be significantly affected for the two high contrast targets (Figure 4). Detection times averaged 2.9 and 15.6 seconds for the 1.0 and 0.5 minute targets respectively. As was the case for the 0.032 inch defect size, these times are slightly better (faster) than those attained with the zero-defect test panel. When the contrast for these same targets was reduced to 10%, detection times increased to 13.8 and 20.4 seconds respectively. Performance was especially affected for the 0.5 minute target when 22 defects were on the panel. Detection times averaged approximately 4.5 seconds longer for this condition.

TABLE 1
Average Time to Detection (Seconds)

		10% Contrast Defect Size				80% Contrast Defect Size			
	No. Defects	0.0	0.032	0.093	0.35	0.0	0.032	0.093	0.35
Tgt.	0	11.8	—	—	—	3.2	—	—	—
Size	11	—	13.1	11.7	13.2	—	2.7	2.6	2.4
1.0′	22	—	13.5	14.5	13.3	—	2.6	2.9	2.9
	33	—	11.7	14.5	12.2	—	2.4	3.0	2.9
	44	—	12.9	14.5	13.1	—	3.1	3.1	3.4
	0	20.0	—	—	—	17.2	—	—	—
	11	—	18.7	20.0	20.0	—	15.9	16.0	15.1
0.5′	22	—	21.2	24.9	21.8	—	15.5	16.6	17.1
	33	—	20.0	16.9	18.9	—	19.1	15.3	15.9
	44	—	17.8	19.7	24.0	—	13.2	14.6	23.0

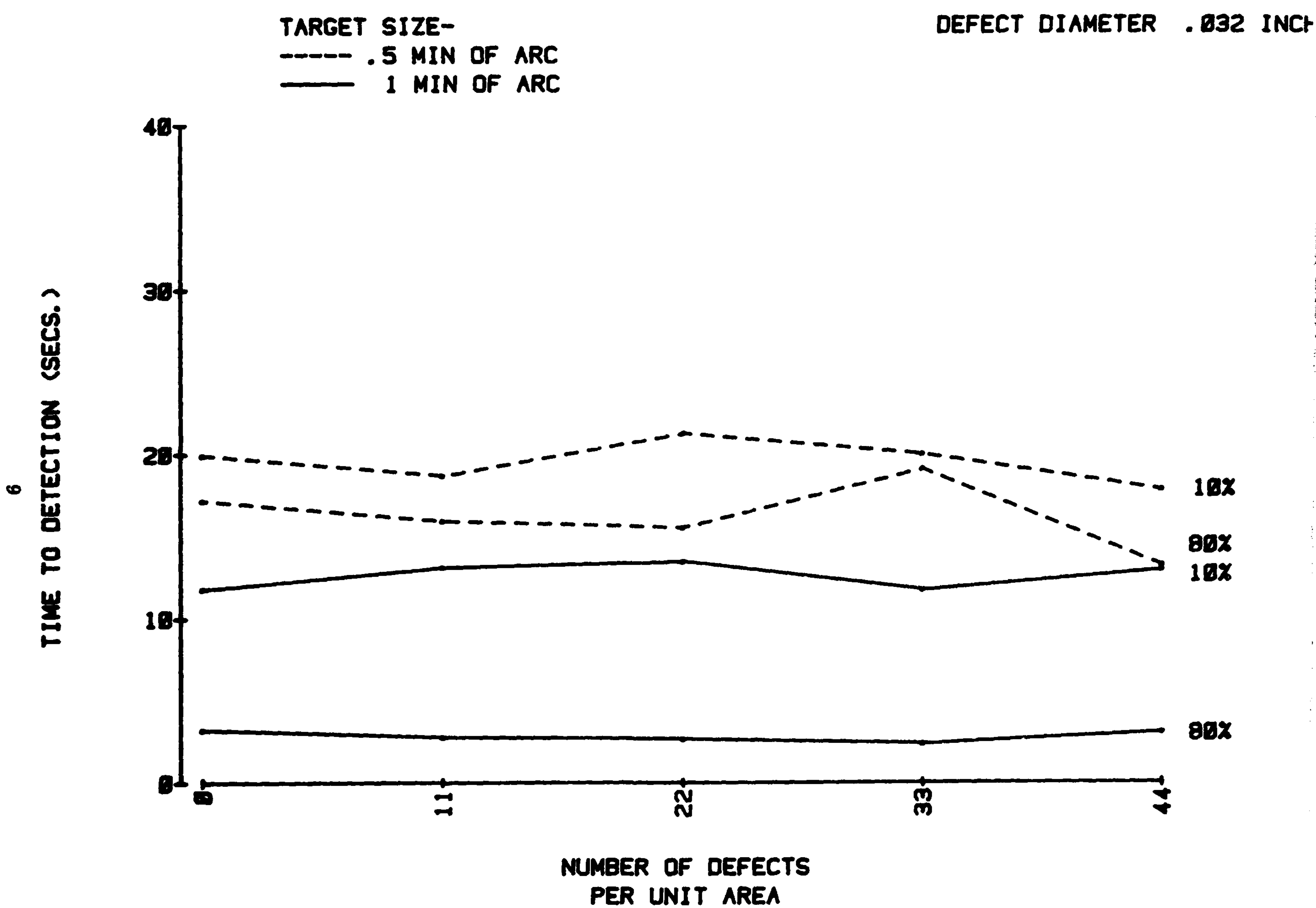

Figure 3. Mean Time to Detection for Target Size and Target Contrast as a Function of Number of Defects (0.032 Inch Defect Size)

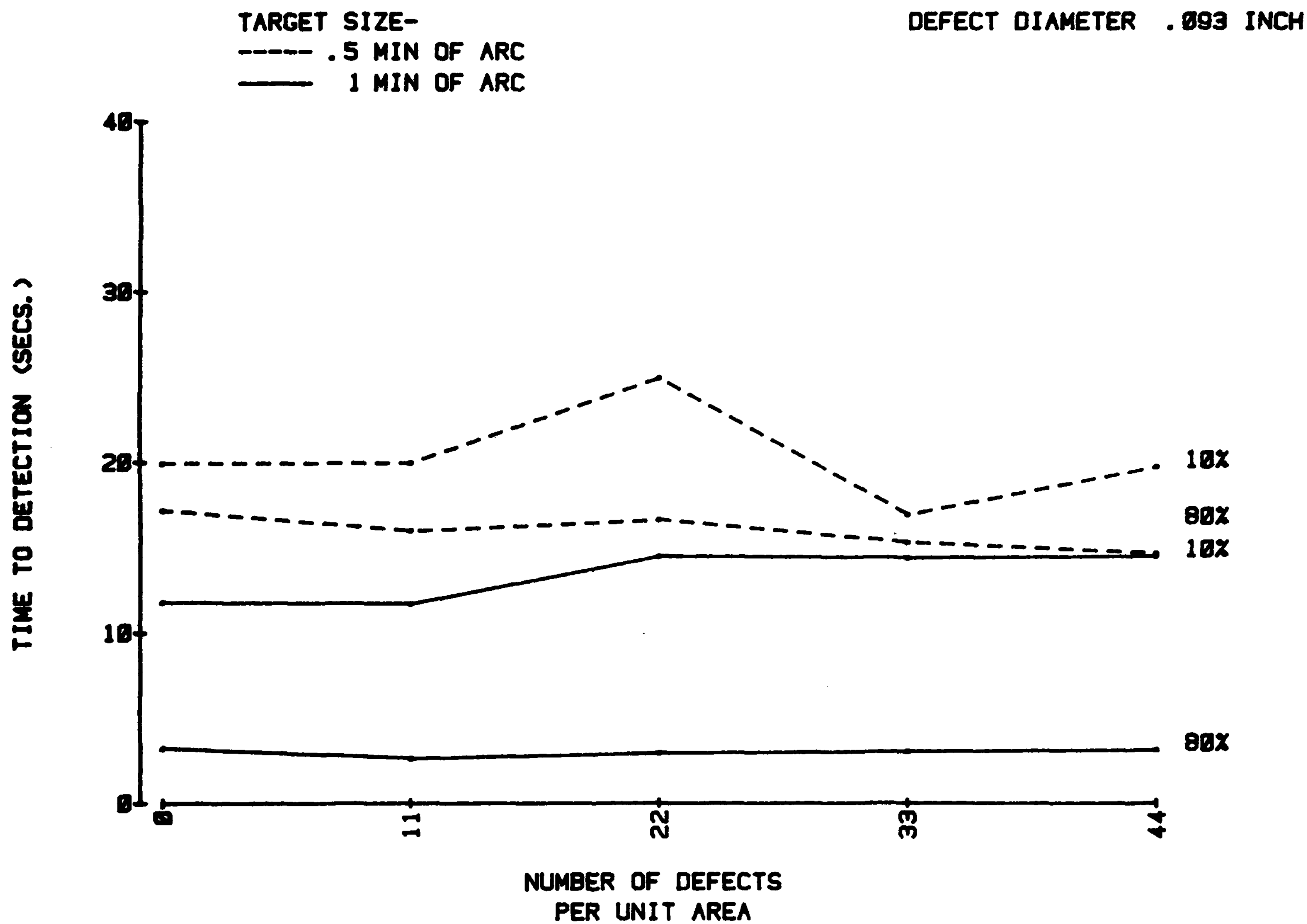

Figure 4. Mean Time to Detection for Target Size and Target Contrast as a Function of Number of Defects (0.093 Inch Defect Size)

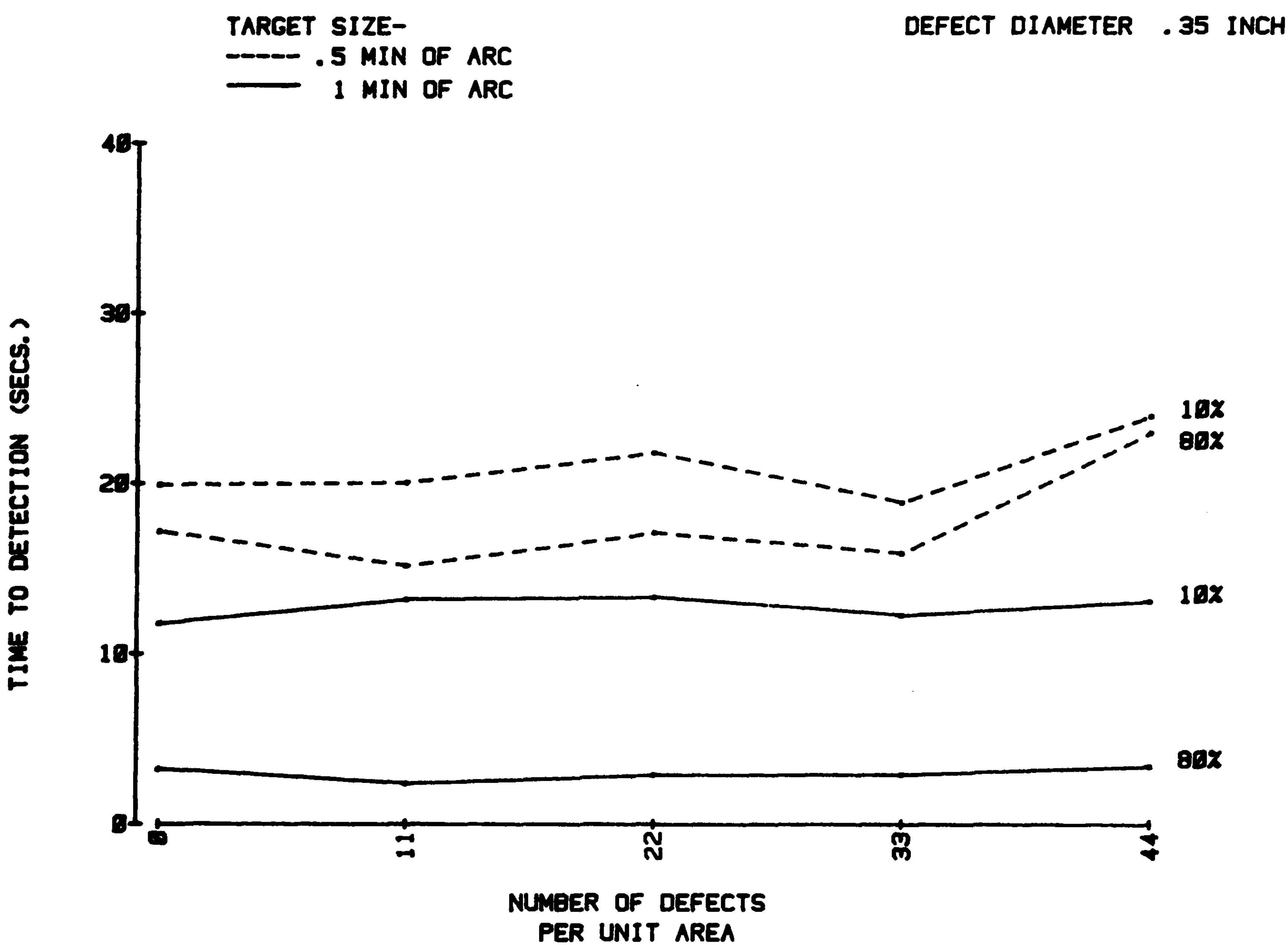

Figure 5. Mean Time to Detection for Target Size and Target Contrast as a Function of Number of Defects (0.35 Inch Defect Size)

Interposition of a panel containing exceedingly large defects (0.35 inches) again resulted in little or no effect on target detection times. Detection times averaged 2.9 and 17.8 seconds for the 1.0 and 0.5 minute high contrast targets respectively. The times for these same targets at the low contrast were 13.0 and 21.2 seconds respectively. However, when the number of defects reached 44, performance in detecting the 0.5 minute target regardless of its contrast level was adversely affected (Figure 5), taking approximately 4 seconds longer on the average. This combination of defect size and number of defects left only 94% of the panel area usable for unobstructed vision.

In terms of correct detections (Table 2), performance with the zero-defect panel yielded 96% correct detections for the 1.0 minute (24,500 foot range) high contrast target and 84% correct detections for the low contrast target. For the 0.5 minute (49,000 foot range) target, these percentages decreased to 66% and 56% for the high and low contrast targets respectively.

Interposition of test panels containing defects of 0.032, 0.093, or 0.35 inches in diameter resulted in detection performances that were superior to that obtained with the zero-defect test panel irrespective of the size or contrast of the target viewed. For the 0.032 inch size defect (Figure 6), detection performances of 99% and 88% were obtained for the 1.0 and 0.5 minute high contrast targets respectively. For these same low contrast targets, performances of 93% and 73% were achieved. The panel containing 0.093 inch size defects (Figure 7) yielded detection performances of 100% and 85% while the panel containing defects of 0.35 inches in size (Figure 8) led to detection performances of 97% and 76% for the 1.0 and 0.5 minute high contrast targets respectively. When the contrast for these targets were reduced, performances of 88% and 63% (Figure 7) and 90% and 59% (Figure 8) were achieved.

TABLE 2
Percent Correct Detections

		10% Contrast				80% Contrast			
			Defect Size				Defect Size		
	No. Defects	0.0	0.032	0.093	0.35	0.0	0.032	0.093	0.35
Tgt. Size	0	84	—	—	—	96	—	—	—
	11	—	95	95	89	—	100	99	99
1.0′	22	—	98	88	91	—	100	100	100
	33	—	91	86	89	—	100	99	94
	44	—	89	81	89	—	95	100	96
	0	56	—	—	—	66	—	—	—
	11	—	70	71	63	—	89	83	83
0.5′	22	—	74	59	65	—	89	93	73
	33	—	74	56	56	—	85	88	81
	44	—	73	66	53	—	88	76	66

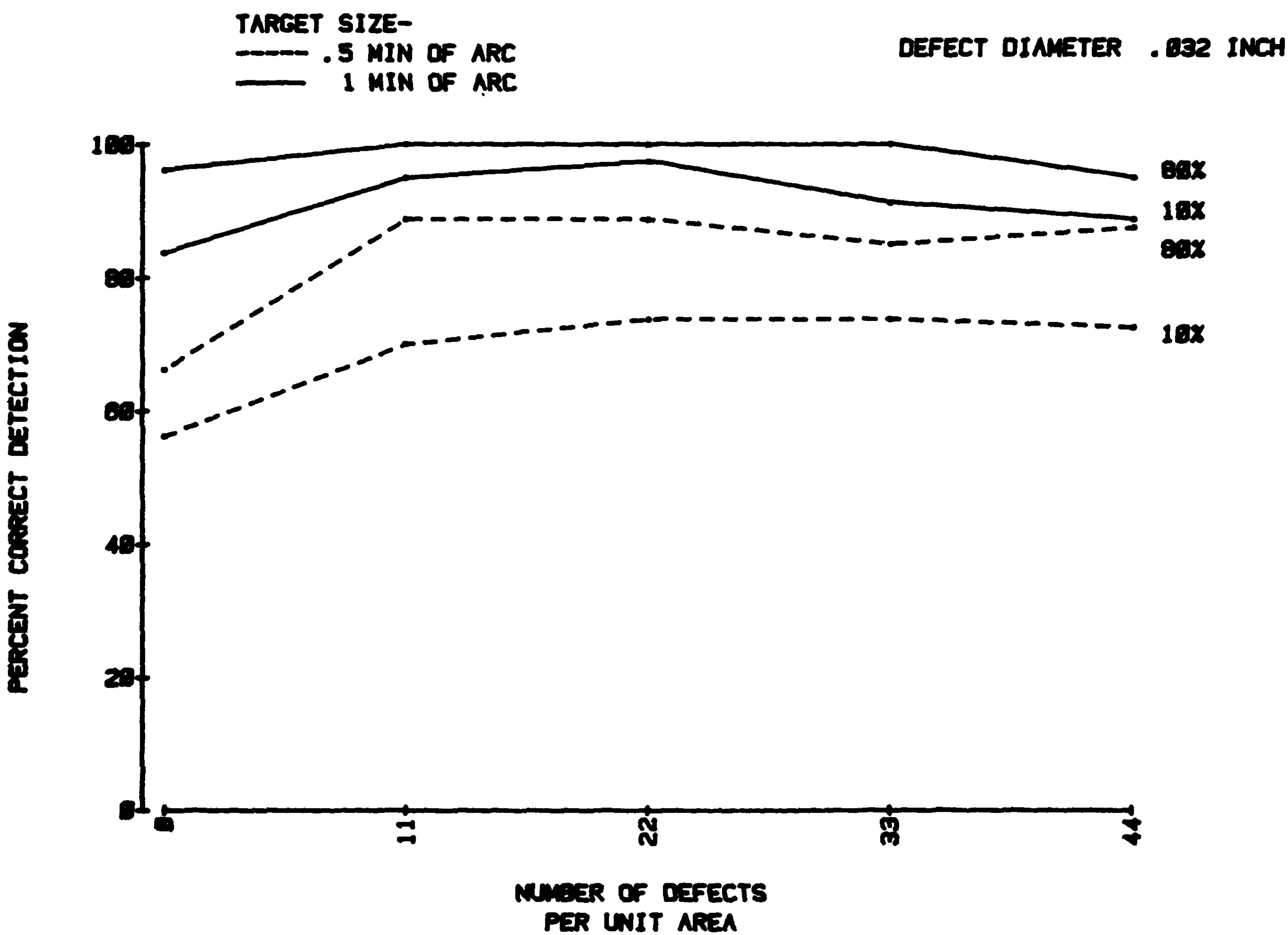

Figure 6. Mean Percent Correct Detections for Target Size and Target Contrast as a Function of Number of Defects (0.032 Inch Defect Size)

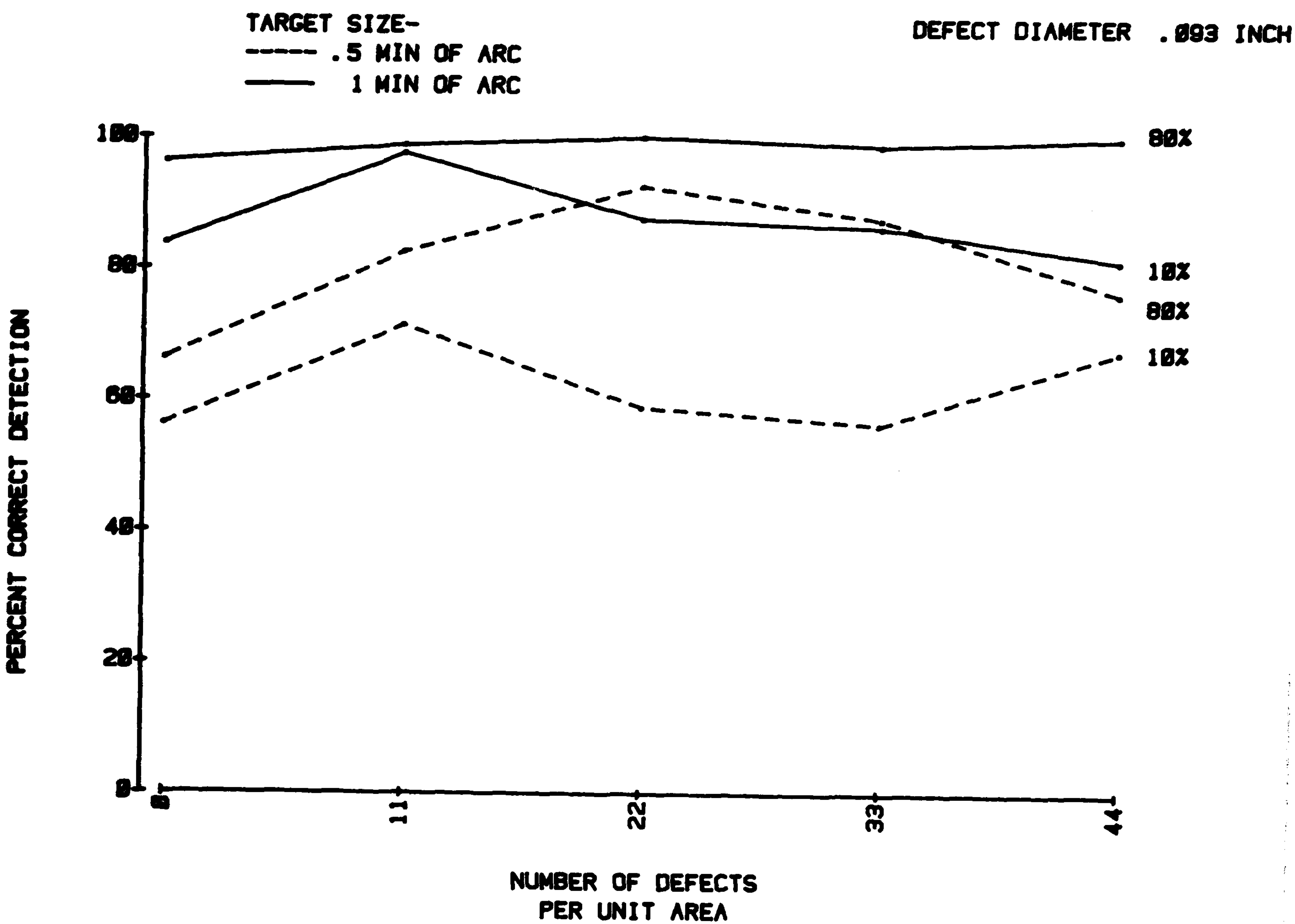

Figure 7. Mean Percent Correct Detections for Target Size and Target Contrast as a Function of Number of Defects (0.093 Inch Defect Size)

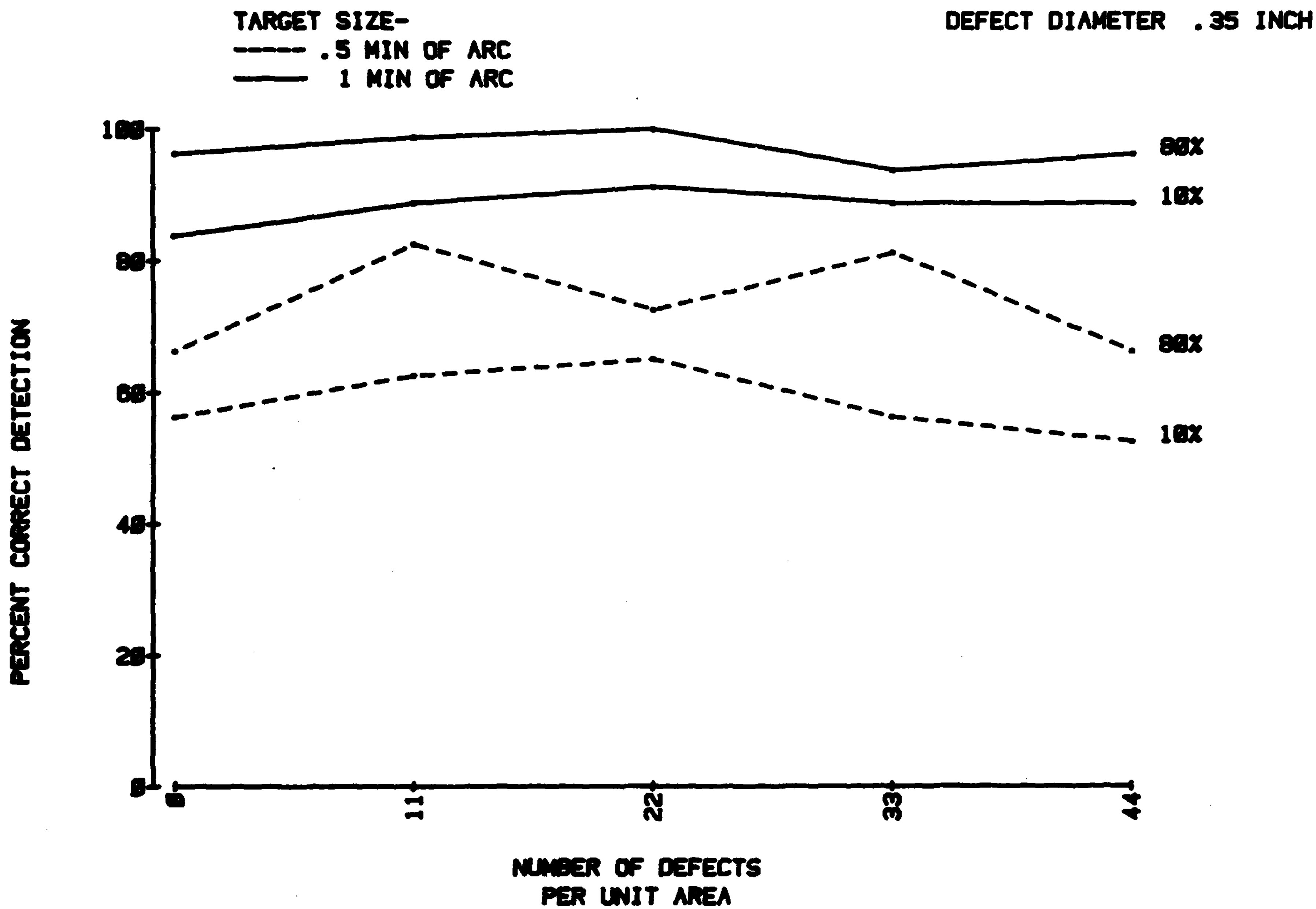

Figure 8. Mean Percent Correct Detections for Target Size and Target Contrast as a Function of Number of Defects (0.35 Inch Defect Size)

SECTION 4
DISCUSSION

As indicated earlier, the purpose of this study was to determine the effect of opaque optical defects of various sizes and densities (number per unit area) on the performance of a target detection task. The data derived from this study can then be used to relate visual performance to requirements specified in the various standards and specifications, as well as acceptance procedures, regarding the size and number of optical occlusions permitted on aircraft transparencies.

Current specifications and acceptance procedures (refs. 1, 4, 5 & 6) indicate that the size of opaque occlusions permitted on windscreens may range from 0.035 to 0.25 inches. This wide range of permissible defect sizes indicates the lack of uniformity among the various specifications and procedures and also suggests that size requirements are probably not related to the visual aspects of flight.

This same state of affairs also exists with regard to the number of defects permitted on the windscreen. The prime consideration is the size of the defect itself, the allowable number varying from a minimum of 1 per square foot to 20 per zone (res. 4, 5, 6, 7, 8, 9 & 10). In several of the specifications, the maximum number of defects allowed is based on the thickness of the sheet employed. If the sheet is 0.5 inches or less in thickness, the maximum number of defects allowed is determined by dividing the area of the sheet by 4. However, if the sheet is over 0.5 inches in thickness the maximum allowed is 2 (ref. 7) or 1 (ref. 9) per square foot. It is difficult to determine what rationale was used to justify this requirement.

The combination of defect size and number of defects employed and the size of the test panels used in this study resulted in test conditions that greatly exceeded the maximum size and number of defects requirements contained in the various specifications and acceptance procedures. Therefore, the data obtained presumably can be used to determine any relationships that may exist between operator visual performance and the number and size of opaque optical defects found in aircraft transparencies.

As indicated in the results section, the most obvious findings are the superiority in performance attained due to the size (the 1 minute target being superior to the 0.5 minute target) or contrast (the 80% contrast target being superior to the 10% contrast target) of the target employed. It is of interest to note that when comparing the relative effects of contrast and range on detection time for the various conditions, it was found that doubling the range increased target detection time by a factor of 5.7 for the high contrast targets and a factor of 1.58 for the low contrast targets. Reducing the contrast of a target by a factor of 8 increased target detection time by approximately a factor of 4.41 for the larger targets and a factor of 1.22 for the smaller targets. This finding indicates that differences in range (size of target) have a much greater impact on target detection time than do differences in contrast, as long as both parameters remain above threshold. Although these findings are valid and of interest, our main concern in this study was to determine the effects of size and number of defects on target detection performance. A closer look at these variables will be accomplished by examining performance within a given target size and contrast level.

Looking first at the 1.0 minute high contrast target, the curves in Figures 3, 4 and 5 indicate that the size of the defect or the number of defects on the test panel had no effect on performance of the required task. All three defect sizes yielded curves that were relatively flat across number of defects. Detection times averaged 2.8 seconds (2.7, 2.9 and 2.9 seconds for the 0.032, 0.093 and 0.35 inch defect size respectively) irrespective of the size of the defect or the number of defects on the test panel. Detection performance (Figures 6, 7 and 8) also reflected no effects due to size and number of defects. Correct detections averaged 99% (99, 100 and 97 percent for the 0.032, 0.093 and 0.35 inch defect size respectively) irrespective of the size and number of defects on the panel. These findings seem to indicate that given a large target of fairly high contrast, performance of a target detection task remains relatively constant whether the task is performed through a test panel containing 44, 33, 22 or 11 defects of sizes 0.032, 0.093 or 0.35 inch diameter. Indeed occurrence of the defects on the test panel may have helped performance as performance with the panels containing the defects were better than the performance obtained with the zero-defect test panel.

However, when the same high contrast target is reduced in size to 0.5 minutes, the variables of size of defect and number of defects appear to have an effect on performance. Looking at Figures 3, 4 and 5, we note that even though detection times for all three defect sizes (0.032, 0.093 and 0.35 inch diameter) averaged 16.4 seconds, the average detection time for the largest defect size was 2 seconds longer (17.8 seconds) than the average times for the two smaller defect sizes (15.9 and 15.6 seconds for the 0.032 and 0.093 inch size respectively). Additionally, detection times were much more variable across number of defects for all three defect sizes with the worse performance (23 seconds) occurring when 44 of the 0.35 inch diameter defects were on the test panel.

Detection performance (Figures 6, 7 and 8) also reflect the same trends exhibited by the detection times. As the size of the defect increased, performance decreased from 88% (0.032 inch size) to 85% (0.093 inch size) to 76% (0.35 inch size). Again, performance is seen to be much more variable as a function of number of defects with the worse performance (66%) again occurring when 44 of the 0.35 inch size defects were on the test panel. It may be assumed, therefore, that a human observer can tolerate the presence of these opaque defects in a far greater number and size than currently specified. Although open to conjecture, it may also be that the size and number of defects permitted on a transparency may not be a valid indicator of the "goodness" or "badness" of that transparency and that perhaps some other indicator should be used. One possible indicator that may prove useful, and perhaps more valid, is an indicator based on percent of unobstructed viewing area. That is, rather than using size and number of defects, it may be more advantageous to specify the requirements in terms of the percent of the windscreen that is obstructed by these opaque defects. For example, the various combinations of defect sizes and number of defects used in this study resulted in 1%, 2%, 3%, 5% or 6% of the total viewing area being obstructed. Since the worse performance (23 seconds detection time and 66% detections and 24 seconds detection time and 53% detections for the high and low contrast 0.5 minute target conditions respectively) occurred when 6% of the panel area was obstructed, the requirement might read "given a viewing area of 254 square inches, not more than 6% of the total viewing area will be obstructed by opaque defects. Additionally, the area immediately in front of the design eye height shall be kept free of any defects. The largest single permissible defect on the windscreen shall not exceed 0.35 inches in diameter". See Appendix A for the procedure used to arrive at the above obstruction percentages.

Before concluding this discussion, a few words are in order regarding the relatively poor performance exhibited by the zero defect test panel. One plausible explanation for the occurrence of this situation was thought to be a procedural one. That is, the zero-defect panel was always presented first and hence was thought to have served as a learning (training) session for subsequent test conditions. However, after the last test session with the low contrast target was completed, the zero defect panel was again tested with the same results obtained; i.e. performance with the zero-defect panel was worse than the performance obtained with the panels containing defects.

A second, and perhaps more reasonable explanation, may be attributed to the operation of several visual effects — Mandelbaum's effect, motion parallax and/or empty field myopia — upon the observer during the performance of the detection task. Mandelbaum (ref. 11) demonstrated in an informal experiment that when distant objects are viewed through an intervening surface that contains resolvable contours, under some conditions accomodation adjusts for the unattended intervening surface despite subjective efforts to focus on the more distant target. He found that a quick movement of the head from side to side brought the target back into focus, but accomodation returned to the intervening surface shortly after this motion stopped.

In the experimental situation employed, i.e., the subject looking through a simulated windscreen at a distant screen to detect a target, the necessary elements for Mandelbaum's effect to occur were clearly present. Although the effect may have been somewhat stronger with the defect-covered panels than with the zero-defect panel, it may have been more easily overcome by the subjects unknowingly moving their heads from side to side to "see" around the defects. With the zero-defect panel, there was no need to move the head. This ability to overcome the accomodative bias of Mandelbaum's effect would account for the better performance achieved with the defect-covered panels as compared with the zero-defect panel.

Movement of the head from side to side also led to the inducement of motion parallax, a strong cue for providing information about objects relative position in the visual field, i.e., whether they are nearer or farther from the observer, based on their appearance or direction of movement. The presence of motion parallax when the defect-covered panels were used should have enhanced detection performance. The results obtained seem to support this supposition.

Finally, the experimental condition in which the subjects looked at the white homogenous background screen through the clear zero-defect panel was conducive to the condition known as empty field myopia, the inability to focus on distant objects. Under such a condition, detection performance should be seriously degraded. The results obtained indicate that such was the case.

It would seem, therefore, that one or all three visual effects had a detrimental effect on detection performance when the zero-defect panel was used or when little or no head movement took place. To determine whether such was indeed the case, a study is being planned to replicate the major conditions of this study. The major exception would be that of immobilizing the observer's head through the use of a bite-bar. This would determine whether head movement was the major factor for the results obtained.

SECTION 5
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

It seems readily apparent that opaque transparency defects greatly exceeding present standards both in size and number may be tolerated by aircrew members with no decrement in their target detection ability. Indeed, these defects may improve target localization in some cases by providing a reference for parallax motion cues. This conclusion is further supported by continued aircrew visual performance after the windscreen has impacted insects during take-off or landings. Insect smears, as measured on F-111 windscreens, often occlude an area ¼ inch wide by 1 inch long and cover an extensive area of the windscreen surface.

RECOMMENDATIONS

It is apparent from the results of this study that present minor defect specifications may be safely relaxed while maintaining equivalent visual performance. This modification of standards would reduce the rejection rate of polycarbonate and acrylic sheeting used in today's plastic transparencies and, concurrently, reduce the per part cost.

Although not as apparent, it may be (as was suggested earlier) that a new manner of specifying the goodness (badness) of a transparency is in order. This new specification would be based on the percent of a given area in the transparency that may be occluded. Based on the findings of this study, this new specification might state that "within any 254 square inch area of an aircraft transparency, the total area that may be obscured by minor defects shall not exceed 6% (15 square inches). Additionally, the largest single defect size allowable within this 254 square inch area shall not exceed 0.35 inches in diameter or occlude 0.1% of this area."

However, before any such proposed standard can be considered or even adopted, it would have to pass some rather stringent validity tests. Such tests should be coordinated with all those agencies who have a vested interest in the development of aircraft transparencies and their standards, e.g., AFWAL/FIEA, and all appropriate SPO's.

APPENDIX A
PROCEDURE USED TO CALCULATE PERCENT OF PANEL OBSTRUCTED

The percent of panel area obstructed was obtained in the following manner: first, the size of the defect used was multiplied by the total number of defects in the test panel employed. The resulting product then represented the total area on the panel that was obstructed. Secondly, this obtained product was divided by the total area of the panel (254 square inches) which yielded the proportion of the total panel area that was obstructed. Finally, the resulting proportion was multiplied by 100 to obtain the percentage of the panel area that was obstructed. Thus, with a defect size of 0.35 inches and a total number of 44 defects, using the above procedure we obtain a 6% obstructed panel area.

EXAMPLE:

1. 0.35 x 44 = 15.4 inches ("area" obstructed by defects).
2. 14.5 x 17.5 = 253.75 or 254 sq. in. (Total panel area).
3. 15.4 : 254 = 0.06 (proportion of panel obstructed)
4. .06 x 100 = 6% (percent of panel obstructed)

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